Fermilab

Section Office
ES&H Section
630.840.8069 (phone)
630.840.3390 (fax)

Memorandum

July 14, 2009

To: Bruce Chrisman

From: Nancy L. Grossman

Subject: Revised FESHM Chapter 5047 Interruptible and Uninterruptible AC Power Back-Up Systems

FESHM Chapter 5047 Interruptible and Uninterruptible AC Power Back-Up Systems has been revised. The following changes apply:

- The requirements applicable to IPS and UPS systems output capability increased from 1 KVA to equal to or greater than 2.5 KVA.
- A note was added on page 5 under "Requirements" to see ESS determinations for additional design guidance. These determinations are referenced at the bottom of page 6 and a link is provided to ESS Determinations.

After final approval, please return this approval page to Katie Kosirog at MS119 for posting on the web.

Encl.

Recommended for Approval:

Bruce Chrisman — Date 7/20/09

Approved:

Piermaria Oddone — Date 7/22/09

INTERRUPTIBLE AND UNINTERRUPTIBLE AC POWER BACK-UP SYSTEMS

INTRODUCTION

Fermilab utilizes a variety of emergency AC power systems to provide back-up power to critical loads in the event of power outages. Larger such systems are gas or diesel powered motor-generators. This chapter does not specifically cover these larger systems. Smaller systems are normally powered by the AC electrical distribution system and employ DC batteries for energy storage of sufficient capacity to back-up the protected load for a specific time period. A first version of the smaller type tolerates an interruption of power to the load and is commonly known as an Interruptible Power Supply (IPS). The IPS type system is typically used for emergency egress lighting. The requirements for testing, documenting and repairing emergency egress lighting are specifically addressed in FESHM Chapter 6011 - "PERIODIC TESTING OF EMERGENCY LIGHTS'. The more common version of the emergency power back-up system is the Uninterruptible Power Supply (UPS) which provides continuous uninterrupted AC power to selected loads. The UPS finds use in backing up computer related systems, critical loads (such as the Comm Center), and also emergency egress lighting systems. The voltage output of IPS and UPS systems are typically 120 or 277 VAC. The ampacity of these systems, rated in KVA, and time of being able to provide emergency power vary from system to system.

Both the IPS and UPS type systems employ Direct Current (DC) to Alternating Current (AC) inverters to provide AC power of proper frequency and voltage and also a charging system to maintain internal DC batteries at full charge. IPS and UPS operation is primarily distinguished in the operation of the inverter. For the IPS, the inverter is ON only during a power outage and is solely powered by internal batteries. For the UPS, the inverter is always ON powering the load. The inverter is normally powered from the AC line and, during a power outage, powered from the internal batteries.

The utilization and maintenance of IPS and UPS systems presents a variety of unique safety concerns and hazards. This chapter describes the design and procedural steps to address these concerns. These requirements are applicable to IPS and UPS systems having output capability that is equal to or greater than 2.5 KVA.

The Department Head or Appointee will be responsible for assuring that maintenance service and testing is performed.

DEFINITIONS

Critical or Standby Power System is a load requirement which provides protection for critical systems such as communications, process loads, spoilage, contamination, hazardous spills or venting, and similar systems which are NOT considered life critical.

DC Battery Voltage - in nominal 12 volt DC rated cells when connected in combination can attain voltages in excess of 250 volts DC.

Emergency Power System is a back-up power system with loads related to life safety support. This can involve any or all the following: emergency egress lighting, EXIT signs, ventilation, fire protection, and emergency response. Design requirements generally follow NFPA 110A and 111 guidelines.

Equalizing Charge is a charge applied to a battery, which is greater than the normal float charge and it is used to completely restore the active materials in the cell, bringing the cell float voltage and the specific gravity of the individual cells back to equal values.

Float Voltage is a continuous voltage supplying a low current from a battery charger applied to a battery in the standby mode to make up for internal losses and maintain the battery in a fully charged state.

High Current DC Battery Power Source is a low voltage source 12-250 VDC, with a designed or rated output current greater than 100-ampere hours.

Interruptible Power Supply (IPS) is an AC battery-supported power supply device intended to provide a backup source of AC power with very short power interruption to the load.

Maintenance Bypass is a means of providing NORMAL AC electrical power to the load whenever UPS or IPS maintenance service is required for the unit equipment. When required, a transfer switch (manual or auto) which can be make-before-break or a simple open-close style switch usually accomplishes this.

Normal Source is understood to be the normal AC power distribution system or utility source of electrical power.

Uninterruptible Power Supply (UPS) is an AC battery-supported power supply device intended to provide a backup source of AC power without power interruption to the connected load.

Unit Equipment is considered a package UPS or IPS system as purchased from a vendor or supplier. This includes, but is not limited to, the housing, charger/inverter electronics package, battery package, internal maintenance bypass (when used),

internal isolating/protection breakers, internal FAX modem (when used), and self-diagnostics or alarm packages.

REQUIREMENTS

1. **General Requirements** - For Units rated 2.5 KVA or more, general requirements shall include the sizing (based on the load and duration of the load) of the unit, the type of power required by the load (frequency, voltage), the system configuration (redundancy, transfer features), protective features, limitations of available ac power, limitations of available dc sources, short-circuit capability, required controls, instrumentation, and alarms. Refer to ANSI/IEEE Std 944 for guidance and criteria for these and other factors to be considered in developing the bases of an UPS system. ANSI/IEEE Std 944 shall be used to develop the bases and requirements of UPS systems with respect to specification of service conditions (environmental), specification of UPS system requirements, and specification of design test requirements. Environmental conditions exceeding the values in ANSI/IEEE Std 944 should be identified and equipment specifically qualified to these different conditions. Refer to guidance and criteria in NFPA 111 and 110 for the development of bases and specifications for transfer switches to be used with UPS designs.

2. **Installation** - The following factors shall be considered in determining if an IPS/UPS installation is acceptable: vibration, temperature, ventilation for hydrogen off gassing and heat removal, local heat sources, power source location, mounting rack (support, insulation, and grounding), seismic needs, and containment for flooded lead acid batteries, instrumentation, and alarms. Refer to IEEE Std 484 for detailed guidance on battery installation, and to IEEE Std 450 (lead-acid) and IEEE Std 1106 (nickel-cadmium) for acceptance testing. Manufacturer's recommendations should be followed, if more limiting, for all batteries, including valve-regulated batteries.

   Requirements for Batteries - The specification of requirements for STATIONARY BATTERIES shall include battery load (load profile), voltage, time period, environment, and installation.

   Battery sizing - Battery load profiles and sizing shall be developed in accordance with IEEE Std 485 (for lead-acid batteries) or IEEE Std 1115 (for nickel-cadmium batteries). This includes type of load, nature of the load (transient and steady state values), timing of application of loads, length of time for each load and overall time needed for battery operation. IEEE Std 485 and IEEE Std 1115 provide detailed instructions on how to treat various types of loads and construct a load profile. Other factors involved in assessing proper battery size include maximum system voltage, minimum acceptable voltage, and battery duty cycle. Cells may be connected in series or series-parallel combinations to arrive at the desired voltage and battery capacity.

Refer to IEEE Std 485 or IEEE Std 1115 as appropriate for detailed guidance on assessing cell and battery size (number and capacity of cells) and for information on the treatment of design margin and the various associated factors to assess whether sizing is adequate.

3. **Power Source Overcurrent and Short Circuit Protection** - All IPS/UPS units shall be protected with primary side breaker protection and shall be coordinated in accordance with NFPA 110 and the NEC Code. The protection equipment shall not be located in the battery compartment of the enclosure.

4. **Internal System Protection** - All IPS/UPS units shall be provided with protection/isolating breakers or fused. Units will be installed with adequate ventilation. Only circuits associated with the unit shall be installed in the same enclosure.

5. **Connection to Multiple Loads Using Multiple Load Breakers** - Use of individual overcurrent load protection devices, such as fuses or circuit breakers, between the IPS/UPS power bus and single load taps is often the most practical solution to the safe powering of multiple loads. This permits the safe utilization of conductors more appropriately sized to the individual load and a means to LOTO these circuits when necessary. All load branches "fed from" the IPS/UPS shall be capable of LOTO isolation - preferably with manufacturer supplied locking hardware. A separate panelboard dedicated to Emergency or Critical load applications shall be used if possible.

6. **Identification and Labeling** - All IPS/UPS units except cord and plug powered units shall have -"fed from" labels on the unit, prominently displayed which indicates the panelboard and circuit breaker supplying normal power and the voltage of the incoming power. A "CAUTION" nameplate is required which describes that when primary power is disabled, battery power generates backup power for approximately "XX" minutes. This "CAUTION" nameplate must also indicate that only authorized personnel can perform maintenance or repair service on the unit. Additionally, a telephone number indicating the "responsible party" to call in the event of a problem must be included on the nameplate.

7. **Maintenance and Safety** - The program should take into consideration the type of service to which the equipment is subjected (duty cycle, chemicals, dust, heat), manufacturers recommendations, and trending. Specific qualification for IPS/UPS systems maintenance personnel should be documented and include the following:

   a. Fundamentals of electrical and electronic design of the IPS/UPS units;
   b. Testing and maintenance practices for IPS/UPS systems;
   c. Specific training on identical or similar equipment to be maintained;
   d. Safety precautions for IPS/UPS systems; and

e. Facility-specific procedures for operations, surveillance, and maintenance.

The IPS/UPS should be checked for evidence of problems by evaluating meter readings and detrimental environmental problems (e.g., heat, moisture, chemicals). Less frequent activities such as internal cleaning, filter replacement, checking electrical connections for tightness, and calibration of instruments shall be done according to manufacturer's recommendations or at least every 18 months. This interval may be adjusted according to documented operating experience. An IPS/UPS in its standby or normal operating mode may not demonstrate many of the various features that may be required to function during emergency conditions, such as a loss-of-power or equipment failure. Depending on the design of the IPS/UPS system, the following tests should be performed:

a. Light-load Test - operation of controls and instruments for stability and values of voltage and frequency;
b. SYNCHRONIZATION Test - measure the rate of frequency change during SYNCHRONIZATION and IPS/UPS voltage during transfer (when an alternate source is part of the design);
c. Alternating Current Input Failure Test - transfers to dc source as designed;
d. Alternating Current Input Return Test - stable return to normal source;
e. Transfer Test - forward and reverse (IPS/UPS systems using static bypass switches);
f. Rated Full-Load Test - connected or rated load carrying capability for the required duration for extremes of ac and dc input voltage;
g. Output-Voltage Balance Test - measure phase angle and voltage to meet specifications for balanced and unbalanced conditions; and
h. Harmonic-Components Test - measure harmonic content in the output voltage for linear and nonlinear load conditions. The tests above correspond to tests recommended by ANSI/IEEE Std 944 and should be performed according to manufacturer's recommendations or on at least an 18-month interval.

8. **Battery Maintenance, Testing, and Surveillance (see reference to ESS Determinations in Additional Design Guidance)** - Batteries shall be monitored, periodically maintained, and properly charged to ensure their readiness to perform. Many types of batteries, if allowed to sit without a charger, will internally discharge, often with irreversible cell degradation. For these types of batteries, it is important to maintain proper charging FLOAT VOLTAGE during standby. Due to inherent differences between cells, FLOAT VOLTAGE and specific gravity values will vary from cell to cell over time. If cell FLOAT VOLTAGES and/or specific gravity values are allowed to remain in an unequal condition for extended periods of time, cell sulfation will result. To overcome this problem, periodic EQUALIZING CHARGE must be applied

to equalize cell voltages and specific gravity. Manufacturer's recommendations should be followed in regard to EQUALIZING CHARGE. When performing an EQUALIZING CHARGE, care should be taken to assure the charger voltage does not exceed the voltage rating of the loads connected during the equalize charge. Batteries are rated at a temperature of 25 degrees C. Higher temperatures will improve capacity at high discharge rates but significantly reduce battery life. Lower temperatures have a significant effect in reducing battery capacity. Typical battery types for standby service are lead-acid (calcium, antimony), pure lead (generally a "round cell"), or nickel-cadmium. IEEE Std 1106 provides criteria and guidance for nickel-cadmium batteries similar to that provided in IEEE Std 450 for lead-acid batteries. Manufacturers will provide necessary information on the care, precautions, charging, and treatment of specific batteries including during periods of storage.

9. **Drawings and Records** - At least two sets of instruction manuals for the IPS/UPS system shall be maintained. The person responsible for coordinating maintenance, service and repair shall have one set and another set shall be available at the unit and they shall contain:

   a. A detailed explanation of the operation of the system.
   b. A schematic wiring diagram.
   c. A functional block diagram.
   d. Battery specifications.
   d. MSDS sheets applicable to the installation.
   e. All manuals supplied by the manufacturer.

ADDITIONAL DESIGN GUIDANCE

"Stationary Lead Acid Battery Maintenance and Test Standard"; Lawrence Livermore National Laboratory; Rev.1, April 15, 1993
Guide Document "Lead Acid Storage Batteries"; Lawrence Livermore National Laboratory; Rev.2, July 1, 1993
Guide Document "Uninterruptible Power Supply (UPS) Systems"; Lawrence Livermore National Laboratory; Rev.1, March 15, 1993
ESS Determination # D2007-3 04-June-2007
http://www-esh.fnal.gov:8001/Electrical/ESS_Determinations.htm

Table A-6-3.2 Solid State Emergency Power Supply Systems Suggested Maintenance Schedule

Item Component (as applicable)	Procedure					Frequency
The suggested maintenance procedure and frequency should follow those recommended by the manufacturer. In the absence of such recommendations, the table below indicates suggested procedures. X Indicates Action R Indicates Replacement If Needed	Visual inspection	Check	Change	Clean	Test	W – Weekly M – Monthly Q – Quarterly S – Semi-Annually A – Annually
1. Battery						
– Float Voltage		X				M
– Cable Connections		X				S
– Terminals				X		Q
– Electrolyte Gravity					X	Q
– Electrolyte Level	X					M
– Replace Cell or Battery			X			See Mfr's Instructions
2. ECE						
– Power Supply Voltage		X				M
– Terminals		X				S
– Panel Meters	X					M
– Panel Lamps	X					M
– Circuit Breakers, Fuses	X	X	R	X		Every 2 Years
3. Battery Charger						
– Output Terminal Volts		X				M
– Fuses	X	X	R	X		Every 2 Years
– Charge Current		X			X	Q
– Equalize Voltage		X				Q
– Panel Meters	X					M
– Panel Lamps	X					M
4. Load						
– Load Current		X				Q
– Panel Meters	X					M
5. Transfer Switch						
– Contacts	X					A
– Test Switch					X	S

Source: NFPA 111